WIM System Field Calibration and Validation Summary Report

Ohio SPS-1
SHRP ID – 390100

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1 Executive Summary

A WIM validation was performed on September 28 and 29, 2010 at the Ohio SPS-1 site located on route US-23 at milepost 19.7, 1 mile north of Radnor Road.

This site was installed on August 15, 1996. The in-road sensors are installed in the southbound lane. The site is equipped with load cell WIM sensors and Mettler-Toledo WIM controller. The LTPP lane is identified as DSP3 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on May 12, 2005 and this validation visit, it is noted that the WIM controller has been replaced, one of the bridge decks was replaced, and the system has been calibrated by the agency during this time.

The equipment is in working order. Electronic and electrical checks of WIM components that were tested determined that the equipment was operating within tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, it was noted that a transition from asphalt to concrete pavement existed approximately 175 feet prior to the WIM scales. Although truck bouncing was observed at this location, these dynamics appeared to diminish prior to trucks traversing the WIM scales. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. The summary results of the validation are provided in Table 1.1 below.

Table 1-1 – Post-Validation Results – 29-Sep-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-3.8 ± 4.5%	Pass
Tandem Axles	±15 percent	-1.5 ± 3.9%	Pass
GVW	±10 percent	-1.8 ± 2.6%	Pass
Vehicle Length	±3 percent (2 ft)	-10.3 ± 2.3 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.2 ± 1.4 ft	FAIL

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was -0.1 ± 2.2 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of -0.1 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.1% is below the 2.0% acceptability criterion for

LTPP SPS WIM sites. The overall misclassification rate of 1.0% from the 100 truck sample (Class 4 – 13) was due to the 5 cross-classifications of Class 4, 5, and 8 vehicles.

There were two test trucks used for the post-validation. They were configured and loaded as follows:

- The *Primary* truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with a forklift over the front half of trailer and crane weight over the rear section.

- The *Secondary* truck was a Class 9 vehicle with air suspension on the tractor tandem, air on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with crane weights over each tandem.

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	10.9	15.6	15.6	16.4	16.4	13.6	4.2	37.2	4.0	59.0	70.4
2	65.8	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

The posted speed limit at the site is 55 mph. During the testing, the speed of the test trucks ranged from to 43 to 59 mph, a range of 16 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 49.3 to 87.6 degrees Fahrenheit, a range of 38.3 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

2 WIM System Data Availability and Pre-Visit Data Analysis

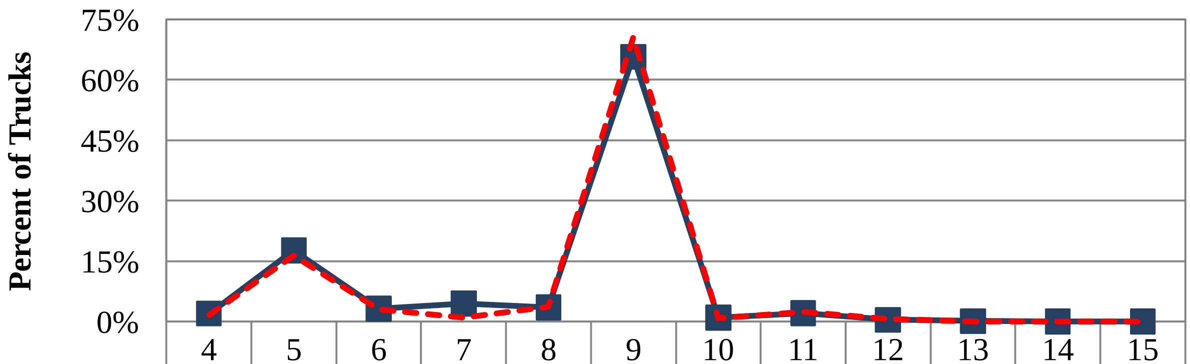
To assess the quality of the current data, a pre-visit analysis was conducted by comparing a two-week data sample from March 13, 2010 (Data) to the most recent Comparison Data Set (CDS) from October 30, 2009. The assessments performed prior to the site visits are used to develop acceptable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 Data Availability

A review of the LTPP Standard Release Database 24 shows that there are 30 consecutive months of level "E" WIM data for this site. This site requires 3 additional years of data to meet the minimum of five years of research quality data.

2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions for the two datasets. As shown in the figure, the two datasets are similar.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	2.0%	17.6%	3.2%	4.5%	3.5%	65.7%	1.0%	2.1%	0.4%	0.1%	0.0%	0.0%
CDS	1.6%	16.4%	3.1%	0.9%	3.7%	70.6%	0.7%	2.4%	0.6%	0.0%	0.0%	0.0%

Figure 2-1 – Comparison of Truck Distribution

Table 2-1 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (65.7%) and Class 5 (17.6%). It also indicates that 0.0 percent of the vehicles at this site are unclassified. Table 2-1 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles.

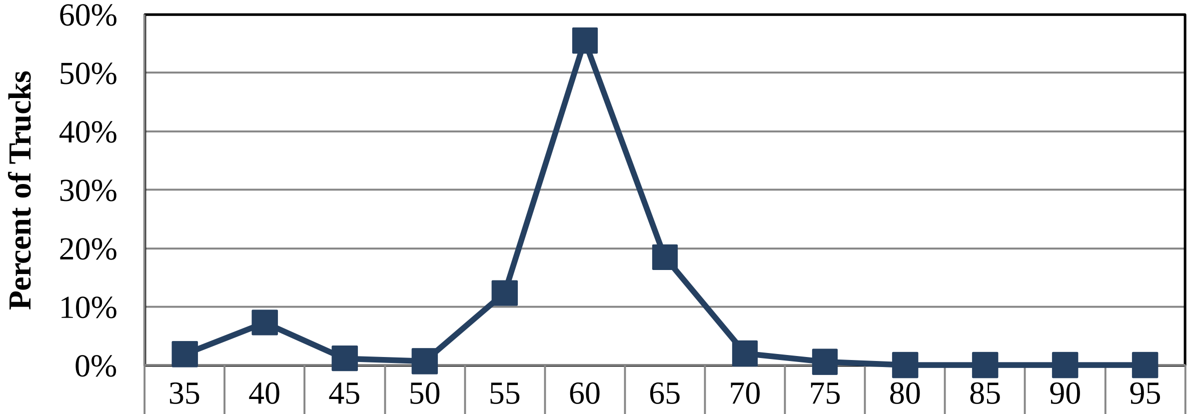
Table 2-1 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
4	946	1.6%	646	2.0%	0.4%
5	9800	16.4%	5790	17.6%	1.2%
6	1836	3.1%	1054	3.2%	0.1%
7	556	0.9%	1468	4.5%	3.5%
8	2214	3.7%	1137	3.5%	-0.3%
9	42111	70.6%	21627	65.7%	-4.8%
10	428	0.7%	325	1.0%	0.3%
11	1413	2.4%	679	2.1%	-0.3%
12	344	0.6%	132	0.4%	-0.2%
13	23	0.0%	30	0.1%	0.1%
14	8	0.0%	8	0.0%	0.0%
15	0	0.0%	0	0.0%	0.0%

From the table it can be seen that the number of Class 9 vehicles has decreased by 4.8 percent from October 2009 to March 2010. Small increases in the number of heavier trucks may be attributed to seasonal variations in truck distributions. During the same time period, the number of Class 5 trucks increased by 1.2 percent. These differences may be attributed to small sample size used to develop vehicle class distributions, decreased use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

2.3 Speed Data Analysis

The traffic data received from the Phase II Contractor was analyzed to determine the expected truck speed distributions. This will provide a basis for the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.



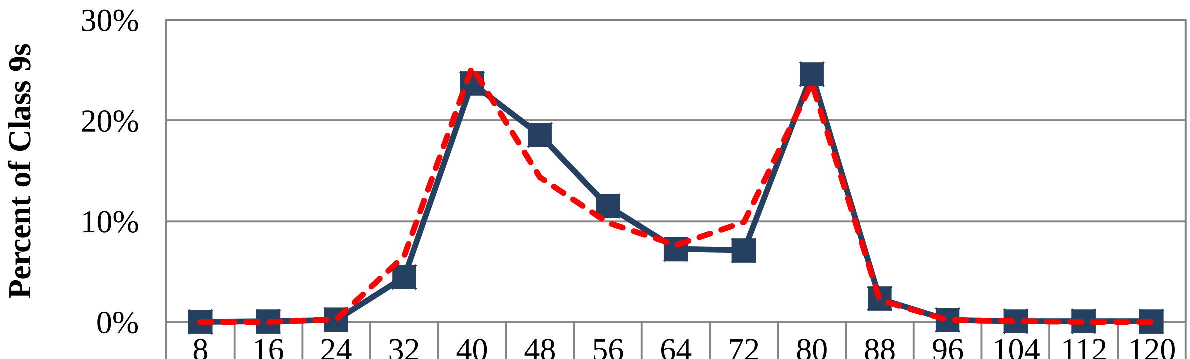
	35	40	45	50	55	60	65	70	75	80	85	90	95
Data	1.9%	7.3%	1.1%	0.7%	12.3	55.5	18.5	2.0%	0.6%	0.0%	0.0%	0.0%	0.0%

Figure 2-2 – Truck Speed Distribution – 22-Sep-10

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 55 and 65 mph. The posted speed limit at this site is 55 and the 85th percentile speed for trucks at this site is 61 mph. The coverage of truck speeds for the validation will be 45 and 55 mph.

2.4 GVW Data Analysis

The traffic CDS data received from the Regional Support Contractor was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from March 2010 and the Comparison Data Set from October 2009. As shown in Figure 2-3, the GVW distribution for each of the datasets is similar.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.2%	4.4%	23.7	18.6	11.5	7.2%	7.1%	24.6	2.3%	0.2%	0.1%	0.1%	0.0%
CDS	0.0%	0.0%	0.3%	6.6%	25.3	14.4	9.8%	7.6%	9.9%	23.7	2.2%	0.2%	0.0%	0.0%	0.0%

Figure 2-3 – Comparison of Class 9 GVW Distribution

Table 2-2 is provided to show the statistical comparison between the Comparison Data Set and the current dataset.

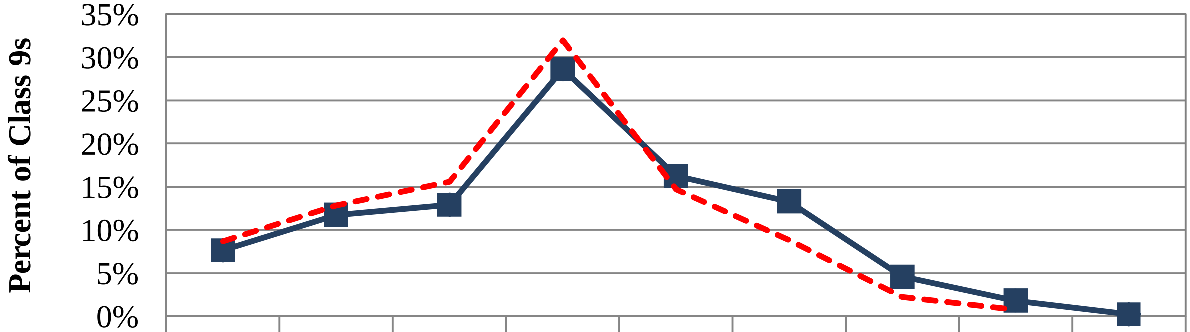
Table 2-2 – Class 9 GVW Distribution from W-Card

GVW weight bins (kips)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
8	0	0.0%	0	0.0%	0.0%
16	10	0.0%	8	0.0%	0.0%
24	110	0.3%	46	0.2%	0.0%
32	2760	6.6%	957	4.4%	-2.1%
40	10626	25.3%	5105	23.7%	-1.6%
48	6041	14.4%	4001	18.6%	4.2%
56	4140	9.8%	2476	11.5%	1.6%
64	3207	7.6%	1555	7.2%	-0.4%
72	4170	9.9%	1528	7.1%	-2.8%
80	9961	23.7%	5298	24.6%	0.9%
88	913	2.2%	498	2.3%	0.1%
96	75	0.2%	40	0.2%	0.0%
104	20	0.0%	16	0.1%	0.0%
112	0	0.0%	13	0.1%	0.1%
120	0	0.0%	7	0.0%	0.0%
Average =	54.1		54.4		0.3

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range decreased by 1.6 percent while the number of loaded class 9 trucks in the 72 to 80 kips range decreased by 0.9 percent. The number of overweight trucks increased during this time period by 0.3 percent and the overall GVW average for this site increased from 54.1 kips to 54.4 kips. None of these changes warrant further investigation.

2.5 Class 9 Front Axle Weight Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average front axle weight. This will provide a basis for the evaluation of the quality of the data by comparing the observed average front axle weight with the expected average front axle weight average for Class 9 trucks of 10.3 kips. Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by the two-week W-card sample from March 2010 and the Comparison Data Set from October 2009.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Data	7.7%	11.7%	12.9%	28.6%	16.3%	13.3%	4.6%	1.8%	0.2%
CDS	8.7%	12.8%	15.5%	32.0%	14.7%	8.8%	2.2%	0.8%	

Figure 2-4 – Distribution of Class 9 Front Axle Weights

It can be seen in the figure that the greatest percentage of trucks have front axle weights averaging 10.5 kips. The percentage of trucks at this weight has decreased between the October 2009 Comparison Data Set (CDS) and the March 2010 dataset (Data).

Table 2-3 provides the Class 9 front axle weight distribution data for the October 2009 Comparison Data Set (CDS) and the March 2010 dataset (Data).

Table 2-3 – Class 9 Front Axle Weight Distribution from W-Card

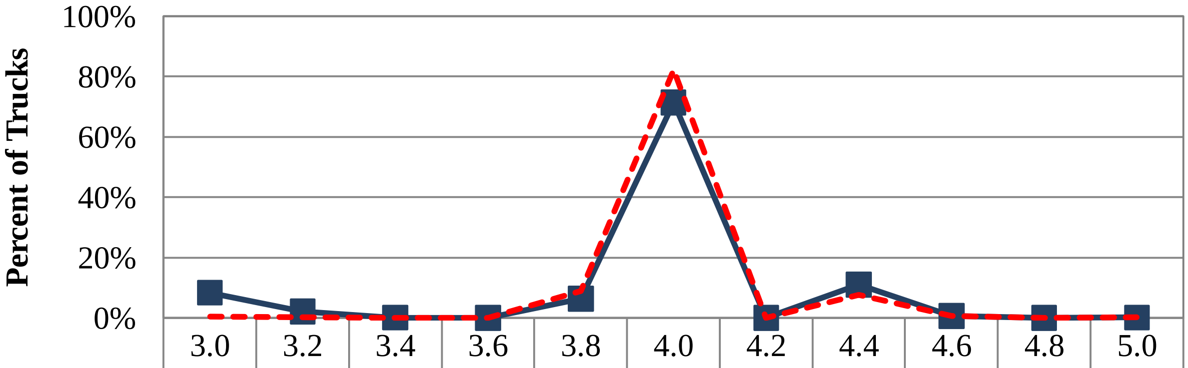
F/A weight bins (kips)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
9.0	1837	4.4%	625	2.9%	-1.5%
9.5	3636	8.7%	1646	7.7%	-1.0%
10.0	5384	12.8%	2526	11.7%	-1.1%
10.5	6526	15.5%	2775	12.9%	-2.6%
11.0	13416	32.0%	6161	28.6%	-3.3%
11.5	6164	14.7%	3498	16.3%	1.6%
12.0	3709	8.8%	2862	13.3%	4.5%
12.5	940	2.2%	983	4.6%	2.3%
13.0	317	0.8%	389	1.8%	1.1%
13.5	51	0.1%	51	0.2%	0.1%
Average =	10.6		10.7		0.2

The table shows that the average front axle weight for Class 9 trucks has increased by 0.1 kips, or 1.8 percent. According to the current data, the majority of the Class 9 front axle weights are between 10.5 and 11.0 kips and the average front axle weight for Class 9 trucks is 10.7 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average tractor tandem spacing. This will provide a basis for the evaluation of the accuracy of the equipment distance and speed measurements by comparing the observed average tractor tandem spacing with the expected average tractor tandem spacing of 4.25 feet.

The class 9 tractor tandem spacing plots in Figure 2-5 are provided to indicate possible shifts in WIM system distance and speed measurement accuracies.



	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Data	8.3%	2.1%	0.1%	0.0%	6.3%	71.4%	0.0%	11.0%	0.7%	0.0%	0.2%
CDS	0.4%	0.2%	0.0%	0.0%	8.8%	82.2%	0.0%	7.7%	0.6%	0.0%	0.1%

Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacing for the October 2009 Comparison Data Set and the March 2010 Data are nearly identical.

Table 2-4 shows the Class 9 axle spacings between the second and third axles for the power unit.

Table 2-4 – Class 9 Axle 3 to 4 Spacing from W-Card

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
3.0	159	0.4%	1796	8.3%	8.0%
3.2	74	0.2%	459	2.1%	2.0%
3.4	19	0.0%	15	0.1%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	3703	8.8%	1359	6.3%	-2.5%
4.0	34542	82.2%	15379	71.4%	-10.8%
4.2	0	0.0%	0	0.0%	0.0%
4.4	3247	7.7%	2363	11.0%	3.2%
4.6	239	0.6%	145	0.7%	0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	50	0.1%	33	0.2%	0.0%
Average =	4.0		3.9		-0.1

From the table it can be seen that the spacing of the tractor tandems for Class 9 trucks at this site is between 3.8 and 4.0 feet. The average tractor tandem spacing is 3.9 feet, which is below the expected average of 4.25 feet. Further analyses are performed during the validation and post-validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (October 2009) based on the last calibration with the most recent two-week WIM data sample from the site (March 2010). Comparison of vehicle class distribution data indicates a 4.8 percent decreased in the number of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 0.1 percent and average Class 9 GVW has increased by 0.6 percent for the March 2010 data. The data indicates an average truck tandem spacing of 3.9 feet, which is below the expected average of 4.25 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on May 12, 2005 and this validation visit, it was noted that the WIM controller was replaced in September of 2008, one of the bridge decks was replaced in November of 2008, and the system was calibrated by the agency during this time.

3.1 Description

This site was installed on March 15, 1996 by Agency. It is instrumented with load cell weighing sensors and Mettler-Toledo WIM Controller. The Agency performs routine equipment maintenance and data quality checks of the WIM data.

3.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented in Section 7.

3.3 Electronic and Electrical Testing

Electronic and electrical checks of system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were not performed; however they appeared to be operating properly. All values for the inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

The WIM system appeared to collect, analyze and report vehicle measurements normally. No troubleshooting actions were taken.

3.5 Recommended Equipment Maintenance

No equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, no areas of pavement distress that may affect the accuracy of the WIM sensors were noted. It was noted that a transition from asphalt to concrete pavement existed approximately 175 feet prior to the WIM scales. Although truck bouncing was observed at this location, these dynamics appeared to diminish prior to trucks traversing the WIM scales.

4.2 Profile and Vehicle Interaction

Profile data was collected on October 20, 2009 by the North Central Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, 900 feet prior to WIM scales and 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000 foot WIM section is 236 in/mi and is located approximately 650 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 550 in/mi and is located approximately 175 feet prior to the WIM scale. This area of pavement was closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed that would influence truck dynamics in the WIM scale area.

4.3 LTPP Pavement Profile Data Analysis

The IRI data files are processed using the WIM Smoothness Index software. The indices produced by the software provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment. The recommended thresholds for WIM Site pavement smoothness are provided in Table 4-1.

Table 4-1 – Recommended WIM Smoothness Index Thresholds

Index	Lower Threshold (m/km)	Upper Threshold (m/km)
Long Range Index (LRI)	0.50	2.1
Short Range Index (SRI)	0.50	2.1
Peak LRI	0.50	2.1
Peak SRI	0.75	2.9

When all values are less than the lower threshold shown in Table 4-1, it is unlikely that pavement conditions will significantly influence sensor output. Values between the threshold values may or may not influence the accuracy of the sensor output and values above the upper threshold would lead to sensor output that would preclude achieving the research quality loading data.

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 5 center profiler runs are presented in Table 4-2.

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass5**	**Avg**
Left	LWP	LRI (m/km)	**2.384**	2.079	0.699			1.721
		SRI (m/km)	1.335	1.289	0.577			1.067
		Peak LRI (m/km)	**2.459**	**2.140**	1.070			1.890
		Peak SRI (m/km)	1.553	1.560	0.699			1.271
	RWP	LRI (m/km)	1.679	1.929	0.715			1.441
		SRI (m/km)	1.135	1.149	*0.469*			0.918
		Peak LRI (m/km)	1.869	**2.106**	0.753			1.576
		Peak SRI (m/km)	1.135	1.154	*0.680*			0.990
Center	LWP	LRI (m/km)	1.714	1.859	1.838	0.590	1.828	1.500
		SRI (m/km)	0.644	0.908	0.881	0.759	0.955	0.798
		Peak LRI (m/km)	1.917	1.972	1.997	1.965	1.976	1.963
		Peak SRI (m/km)	0.761	0.958	0.933	0.820	0.993	0.868
	RWP	LRI (m/km)	1.347	1.370	1.251	1.327	1.325	1.324
		SRI (m/km)	*0.388*	*0.435*	*0.449*	0.597	*0.489*	*0.467*
		Peak LRI (m/km)	1.605	1.647	1.566	1.600	1.609	1.605
		Peak SRI (m/km)	*0.586*	*0.594*	*0.590*	*0.675*	*0.591*	*0.611*
Right	LWP	LRI (m/km)	1.280	1.345	1.358			1.328
		SRI (m/km)	0.585	*0.455*	0.770			0.603
		Peak LRI (m/km)	1.604	1.644	1.539			1.596
		Peak SRI (m/km)	*0.632*	*0.533*	0.790			*0.652*
	RWP	LRI (m/km)	1.603	1.616	1.603			1.607
		SRI (m/km)	0.589	0.549	0.596			0.578
		Peak LRI (m/km)	**2.137**	2.078	1.963			2.059
		Peak SRI (m/km)	*0.687*	*0.588*	*0.693*			*0.656*

From Table 4-2 it can be seen that most of the indices computed from the profiles are between the upper and lower threshold values, with the remaining values over the upper threshold. The highest values, on average, are the Peak LRI values in the right wheel path of the right shift passes..

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the pre-validation, the calibration, and the post-validation test truck runs, as well as information resulting from the classification and speed studies. All analyses of test truck data and information on necessary equipment adjustments are provided.

5.1 Pre-Validation

The first set of test runs provides a general overview of system performance prior to any calibration adjustments for the given environmental, vehicle speed and other conditions.

The 42 pre-validation test truck runs were conducted on September 27, 2010, beginning at approximately 7:51 AM and continuing until 3:00 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with forklifts over front half of trailer and crane weight over rear tandem, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck, loaded with crane weights over each tandem, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the pre-validation and were re-weighed at the conclusion of the pre-validation. The average test truck weights and measurements are provided in Table 5-1.

Table 5-1 - Pre-Validation Test Truck Weights and Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	11.0	15.6	15.6	16.5	16.5	13.6	4.2	37.2	4.0	59.0	70.4
2	65.9	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

Test truck speeds varied by 15 mph, from 45 to 60 mph. The measured pre-validation pavement temperatures varied 5.3 degrees Fahrenheit, from 53.2 to 58.5. The rainy weather conditions prevented for reaching the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

Table 5-2 – Pre-Validation Overall Results – 28-Sep-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	+20 percent	-4.4 ± 3.5%	Pass
Tandem Axles	+15 percent	-1.6 ± 3.2%	Pass
GVW	+10 percent	-1.9 ± 2.2%	Pass
Vehicle Length	±3 percent (2 ft)	-9.4 ± 2.2 ft	FAIL
Axle Length	+ 0.5 ft [150mm]	1.1 ± 0.7 ft	FAIL

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was 0 ± 1.1 mph, which is greater than the +1.0 mph tolerance established by the LTPP Field Guide. Since the site is measuring axle spacing length with a mean error of 1.1, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is not set correctly and that the speeds being reported by the WIM equipment are not within acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3 below.

Table 5-3 – Pre-Validation Results by Speed – 28-Sep-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		45.0 to 49.0 mph	49.1 to 54.0 mph	54.1 to 60.0 mph
Steering Axles	+20 percent	-4.9 ± 3.8%	-4.5 ± 3.5%	-3.5 ± 3.5%
Tandem Axles	+15 percent	-1.3 ± 1.9%	-1.9 ± 4.3%	-1.5 ± 3.6%
GVW	+10 percent	-1.8 ± 1.1%	-2.2 ± 3.3%	-1.7 ± 2.0%
Vehicle Length	±3 percent (2 ft)	-9.4 ± 2.5 ft	-9.7 ± 2.4 ft	-9.0 ± 2.0 ft
Vehicle Speed	± 1.0 mph	0.2 ± 1.6 mph	-0.1 ± 0.9 mph	0.0 ± 0.0 mph
Axle Length	+ 0.5 ft [150mm]	1.1 ± 0.7 ft	1.0 ± 0.9 ft	1.1 ± 0.8 ft

From the table, it can be seen that the WIM equipment estimates all weights with acceptable accuracy and the range of errors is consistent at all speeds. There does not appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following sections.

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment estimated GVW with acceptable accuracy at all speeds. The range in error is greater at the medium speeds when compared with low and high speeds. Distribution of errors is shown graphically in the following figure.

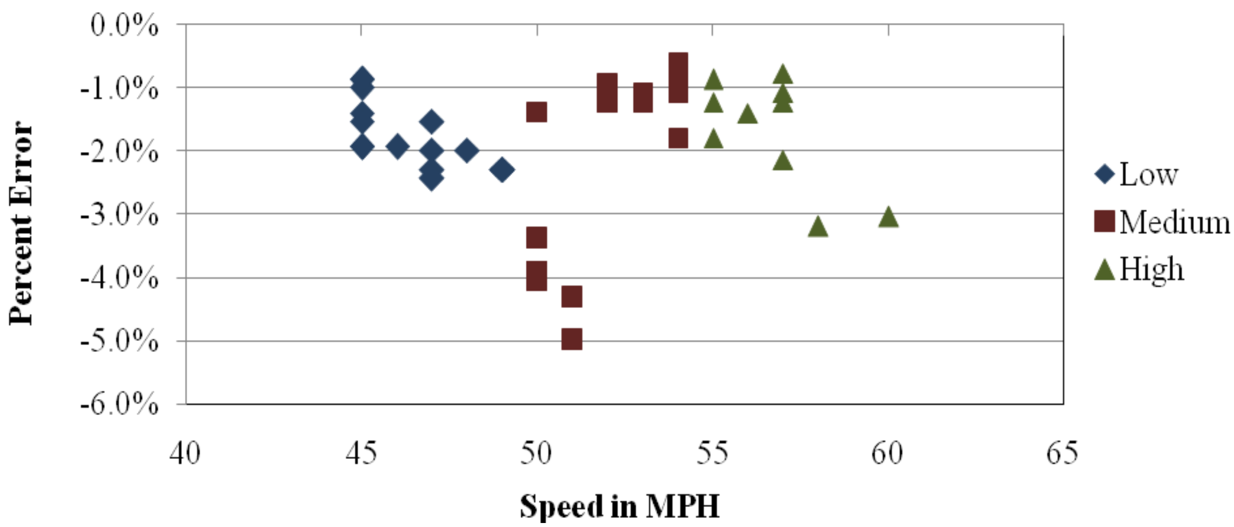


Figure 5-1 – Pre-Validation GVW Error by Speed – 28-Sep-10

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment underestimates steering axle weights with similar bias at all speeds. The range in error appears to be consistent throughout the entire speed range. Distribution of errors is shown graphically in the following figure.

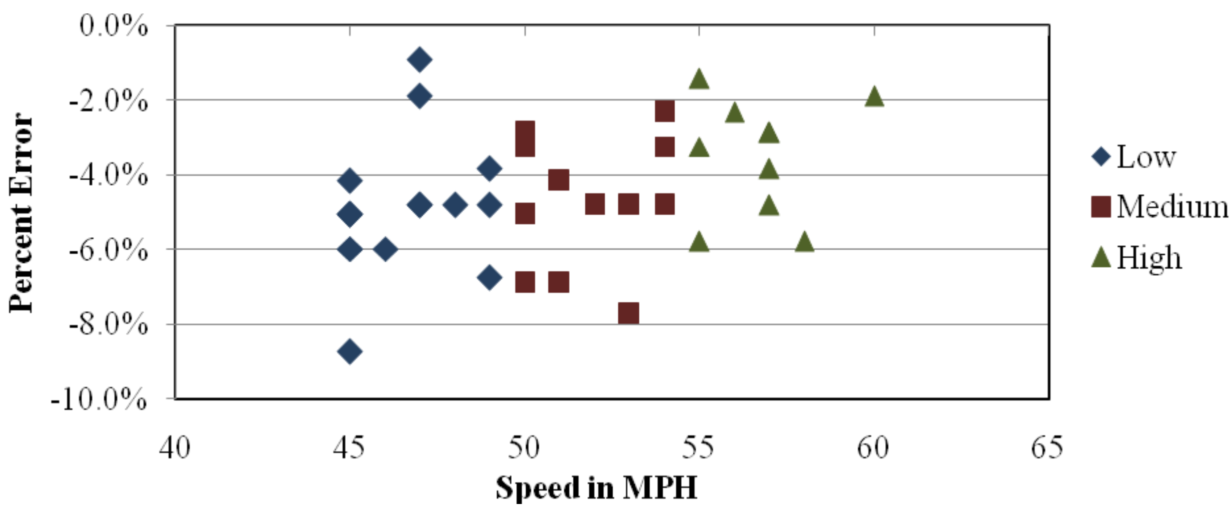


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 28-Sep-10

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment underestimates tandem axle weights with similar bias at all speeds. The range in error is similar throughout the entire speed range. Distribution of errors is shown graphically in the following figure.

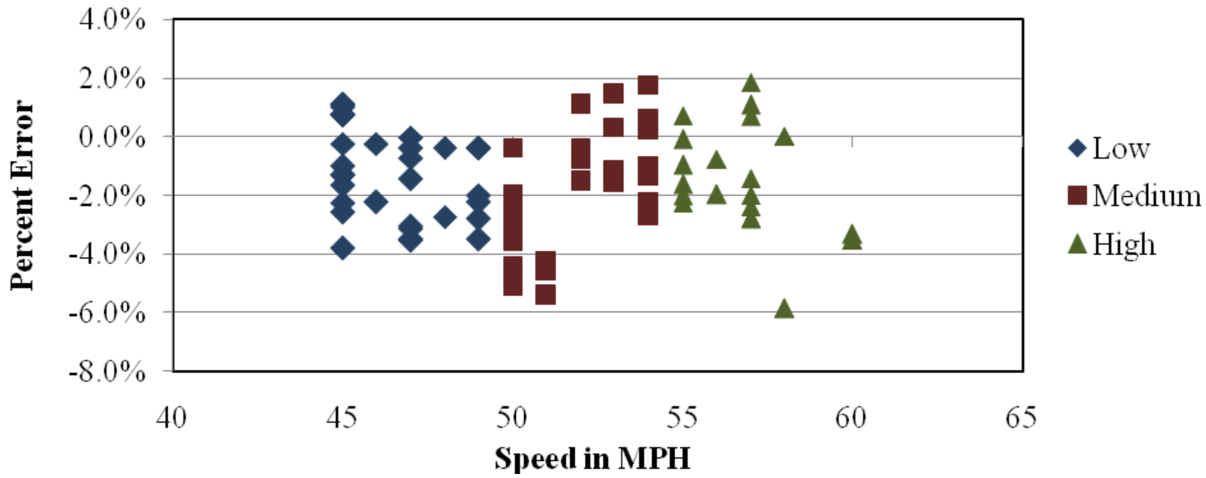


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 28-Sep-10

5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck at the low and high speeds. The equipment underestimates GVW for the Primary truck to a greater degree at the medium speeds, resulting in a greater spread in errors for the trucks at those speeds.

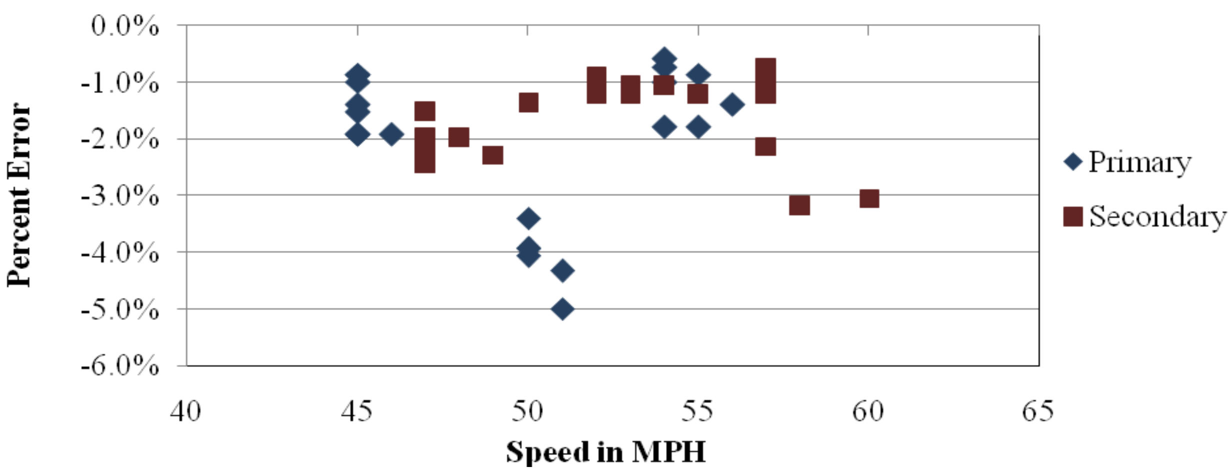


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 28-Sep-10

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.1 feet to 1.9 feet. Distribution of errors is shown graphically in Figure 5-5.

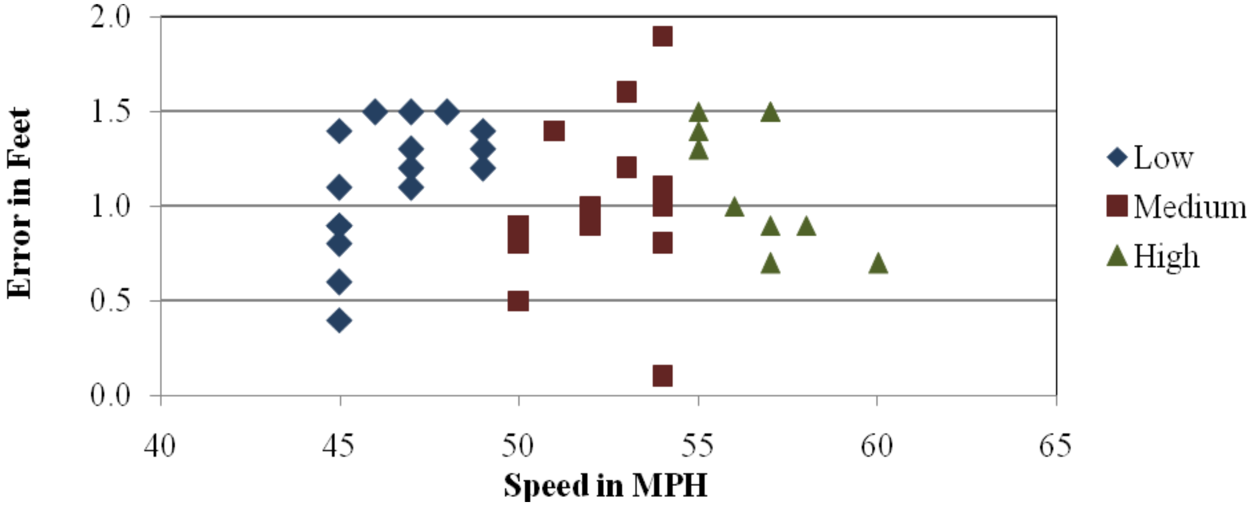


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 28-Sep-10

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment underestimated overall vehicle length consistently over the entire range of speeds, with an error range of -11.3 to -7.7 feet. Distribution of errors is shown graphically in Figure 5-6.

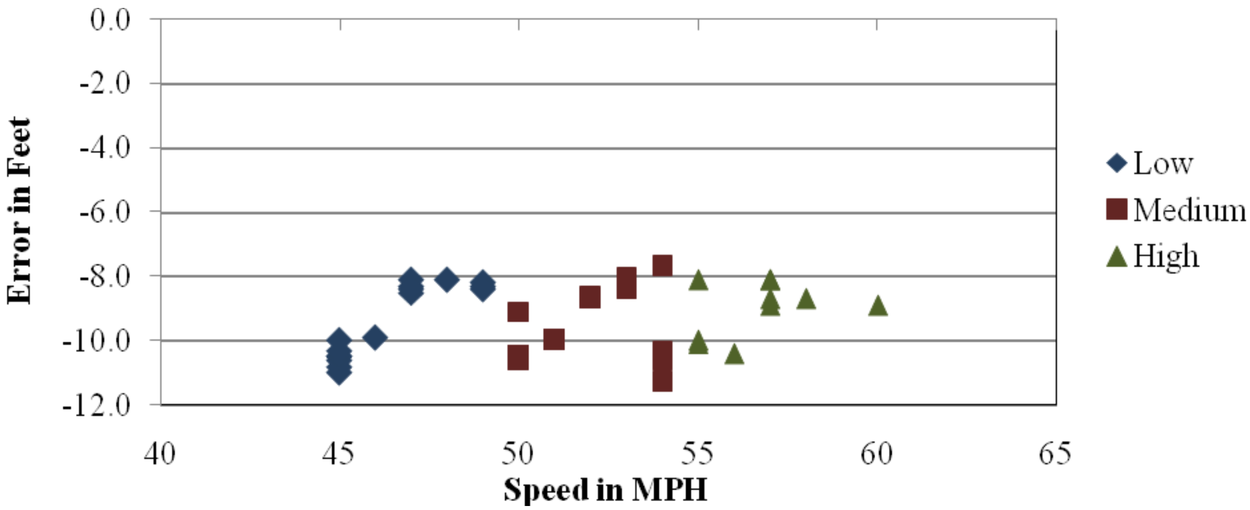


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 28-Sep-10

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 5.3 degrees, from 53.2 to 58.5 degrees Fahrenheit. The pre-validation test runs are being reported under one temperature groups as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 28-Sep-10

Parameter	95% Confidence Limit of Error	Medium
		53.2 to 58.5 degF
Steering Axles	±20 percent	-4.4 ± 3.5%
Tandem Axles	±15 percent	-1.6 ± 3.2%
GVW	±10 percent	-1.9 ± 2.2%
Vehicle Length	±3 percent (2 ft)	-9.4 ± 2.2 ft
Vehicle Speed	± 1.0 mph	0 ± 1.1 mph
Axle Length	± 0.5 ft [150mm]	1.1 ± 0.7 ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle, and axle group weights.

5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

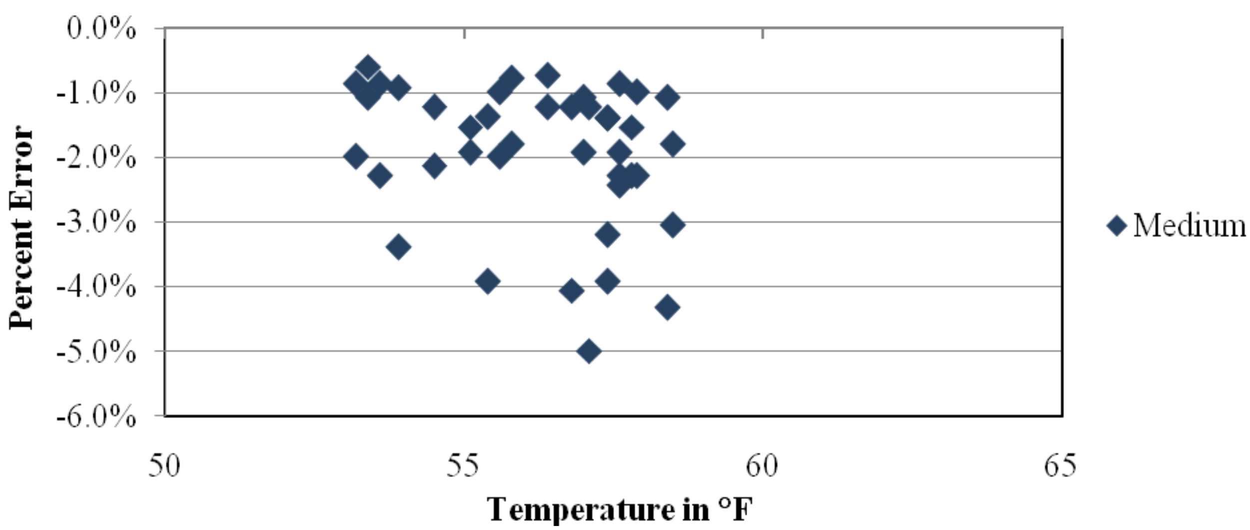


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 28-Sep-10

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 demonstrates that for loaded steering axles, the WIM equipment underestimates steering axle weights at all temperatures. The range in error is similar for different temperature groups.

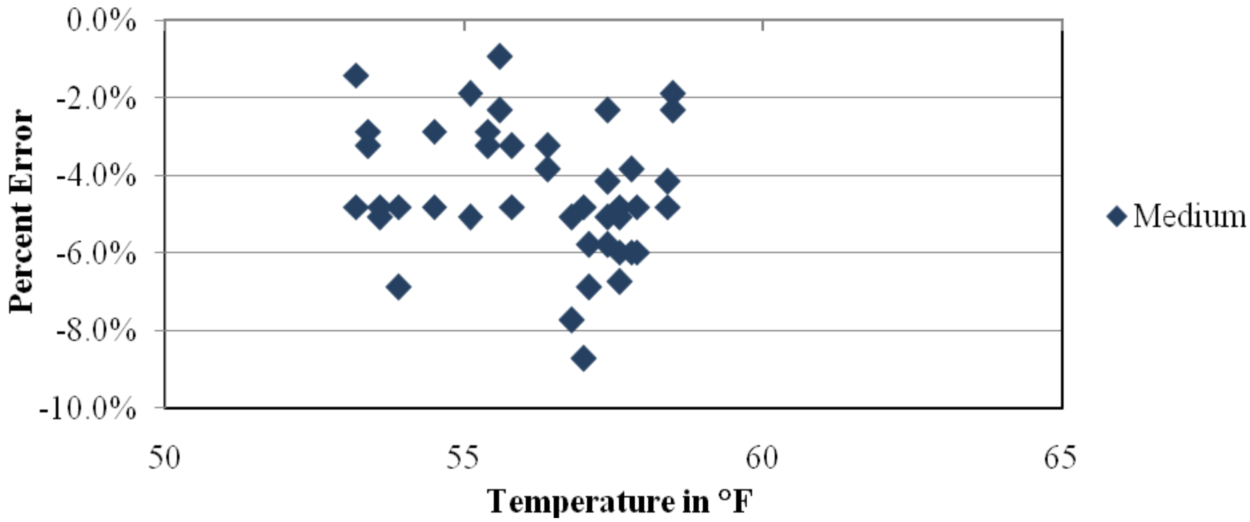


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 28-Sep-10

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the equipment estimates loaded tandem axle weights with acceptable accuracy at all temperatures. The range in tandem axle errors is consistent for the one temperature group. Distribution of errors is shown graphically in the following figure.

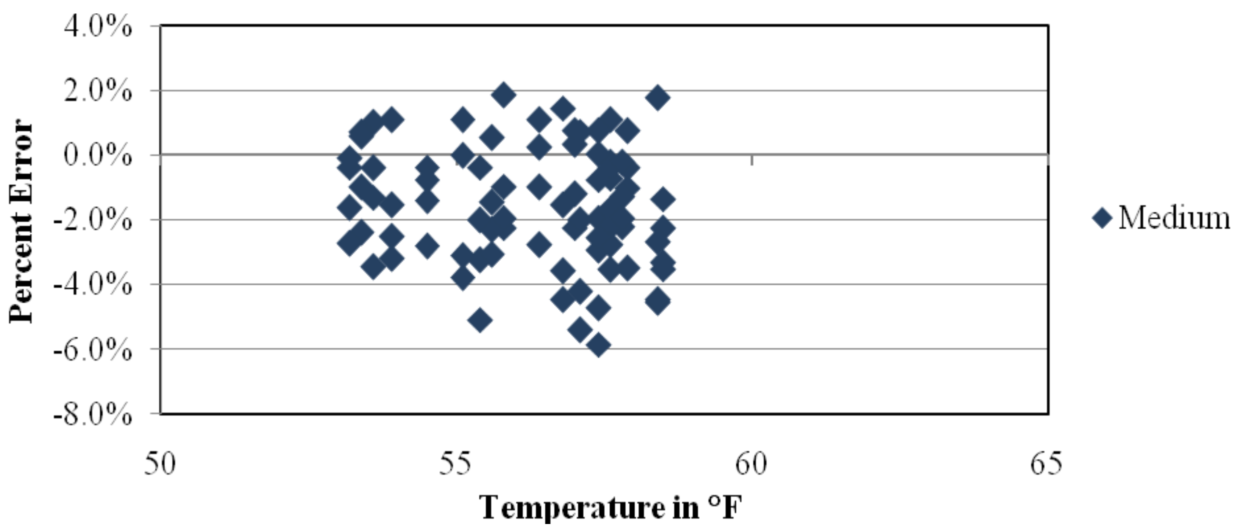


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 28-Sep-10

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, GVW measurement errors for both trucks follow similar patterns where GVW is estimated with acceptable accuracy for each truck at all temperatures. When analyzed independently, the range in errors for the Primary truck is greater than the Secondary truck at all temperatures. Distribution of errors is shown graphically in Figure 5-10.

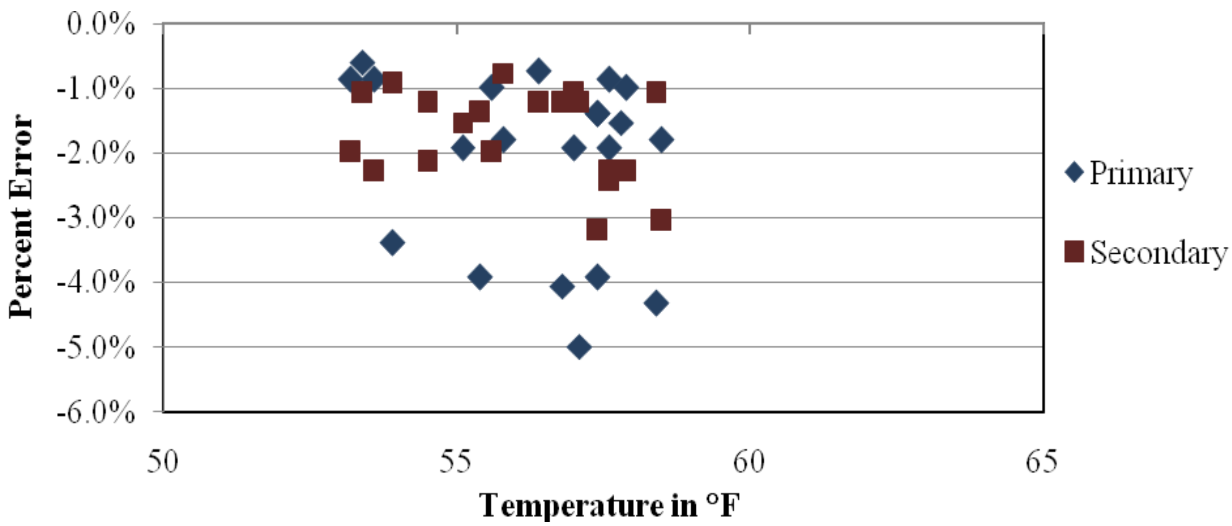


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 28-Sep-10

5.1.3 Classification and Speed Evaluation

The pre-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment. For this equipment, weight is not considered for classification purposes.

For the pre-validation classification study at this site, a manual sample of 100 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field. Table 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-5 – Pre-Validation Classification Study Results – 28-Sep-10

Class	4	5	6	7	8	9	10	11	12	13
Observed Count	0	12	1	0	4	81	2	0	0	0
WIM Count	2	7	0	0	5	80	2	0	0	0
Observed Percent	0	12	1	0	4	81	2	0	0	0
WIM Percent	2	7	0	0	5	80	2	0	0	0
Misclassified Count	0	5	1	0	1	0	0	0	0	0
Misclassified Percent	N/A	42	100	N/A	20	0	0	N/A	N/A	N/A
Unclassified Count	0	0	0	0	0	1	0	0	0	0
Unclassified Percent	0	0	N/A	N/A	0	1	0	N/A	N/A	N/A

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The misclassifications by pair are provided in Table 5-6.

Table 5-6 – Pre-Validation Misclassifications by Pair – 28-Sep-10

Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs
3/5	0	5/9	0	9/5	0
3/8	0	6/4	1	9/8	0
4/5	0	6/7	0	9/10	0
4/6	0	6/8	0	10/9	0
5/3	3	6/10	0	10/13	0
5/4	1	7/6	0	11/12	0
5/6	0	8/3	0	12/11	0
5/7	0	8/5	0	13/10	0
5/8	1	8/9	0	13/11	0

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 1.1% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 6.0%.

As shown in the table, a total of 6 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. The majority of the misclassifications were Class 5s identified by the WIM equipment as Class 3, 4 or 8. For trucks, one Class 6 was identified by the system as a Class 4. The cause of the misclassification was not investigated in the field.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-7.

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 28-Sep-10

Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs
3/15	0	7/15	0	11/15	0
4/15	0	8/15	0	12/15	0
5/15	0	9/15	1	13/15	0
6/15	0	10/15	0		

Based on the manually collected sample of the 100 trucks, 1.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites. The unclassified vehicle was a single Class 9 which could not be identified by the WIM equipment. The cause of the unclassification was not investigated in the field.

For speed, the mean error for WIM equipment speed measurement was 1.5 mph; the range of errors was 3.3 mph.

5.2 Calibration

The WIM equipment required no calibration iterations for weight between the pre- and post-validations. A calibration for the distance was performed. The bias in overall length measurement or steering axle weight could not be compensated for by this equipment, as no system factor for those elements exists. From the information made available to the validation team by the Agency and Mettler-Toledo representatives on site, only one speed factor (55) was available for calibration. Since the estimated weights at this speed appeared to be acceptable, no adjustments to this factor were made.

5.3 Post-Validation

The 47 post-validation test truck runs were conducted on September 29, 2010, beginning at approximately 9:09 AM and continuing until 3:16 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with a forklift over the front half of the trailer and crane weight over the rear tandem, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck, loaded with crane weights over each tandem, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the post-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-8.

Table 5-8 - Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	10.9	15.6	15.6	16.4	16.4	13.6	4.2	37.2	4.0	59.0	70.4
2	65.8	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

Test truck speeds varied by 16 mph, from 43 to 59 mph. The measured post-validation pavement temperatures varied 38.3 degrees Fahrenheit, from 49.3 to 87.6. The sunny weather conditions provided for reaching the desired 30 degree temperature range. Table 5-9 is a summary of post validation results.

Table 5-9 – Post-Validation Overall Results – 29-Sep-10

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	-3.8 ± 4.5%	Pass
Tandem Axles	±15 percent	-1.5 ± 3.9%	Pass
GVW	±10 percent	-1.8 ± 2.6%	Pass
Vehicle Length	±3 percent (2 ft)	-10.3 ± 2.3 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.2 ± 1.4 ft	FAIL

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was -0.1 ± 2.2 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.2, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relation exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-10 below.

Table 5-10 – Post-Validation Results by Speed – 29-Sep-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		43.0 to 49.0 mph	49.1 to 54.0 mph	54.1 to 59.0 mph
Steering Axles	±20 percent	-4.9 ± 2.8%	-3.5 ± 5.8%	-2.8 ± 4.2%
Tandem Axles	±15 percent	-1.2 ± 4.1%	-1.2 ± 4.2%	-2.4 ± 3.2%
GVW	±10 percent	-1.7 ± 3.0%	-1.5 ± 2.9%	-2.3 ± 2.1%
Vehicle Length	±3 percent (2 ft)	-10.6 ± 2.8 ft	-10.4 ± 2.5 ft	-9.9 ± 1.4 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 2.5 mph	-0.5 ± 2.0 mph	0.6 ± 1.7 mph
Axle Length	± 0.5 ft [150mm]	0.2 ± 1.5 ft	0.2 ± 1.4 ft	0.0 ± 1.6 ft

From the table, it can be seen that the WIM equipment estimates all weights with acceptable accuracy and the range of errors is consistent at all speeds. There does not appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following paragraphs.

5.3.1.1 GVW Errors by Speed

As shown in Figure 5-11, the equipment estimated GVW with acceptable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range. Distribution of errors is shown graphically in the figure.

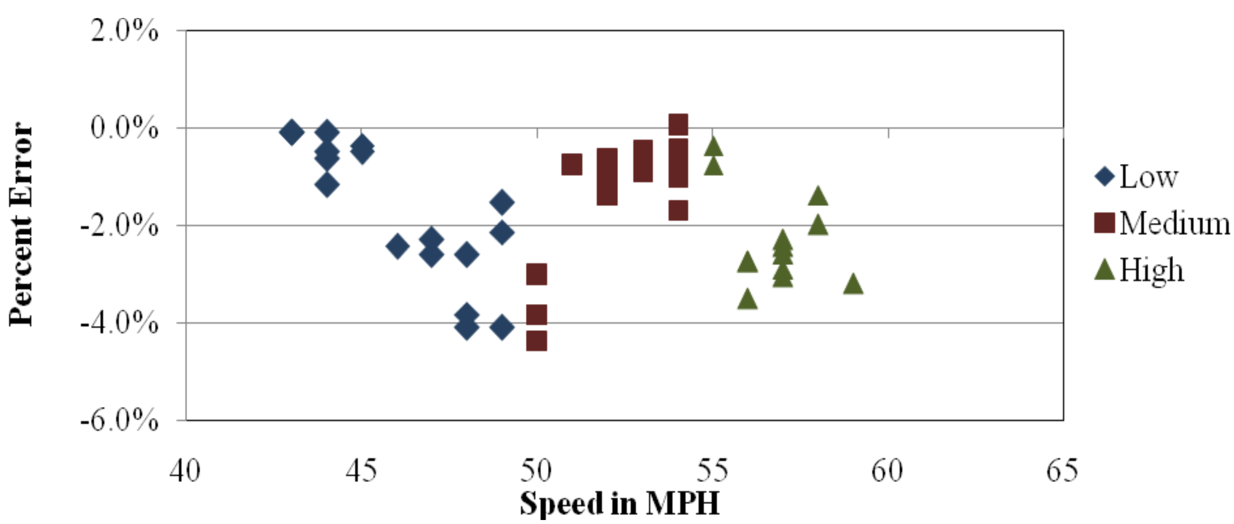


Figure 5-11 – Post-Validation GVW Errors by Speed – 29-Sep-10

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-12, the equipment estimated steering axle weights with acceptable accuracy at all speeds. The range in error is greater at the medium speeds when compared with the low and high speeds.

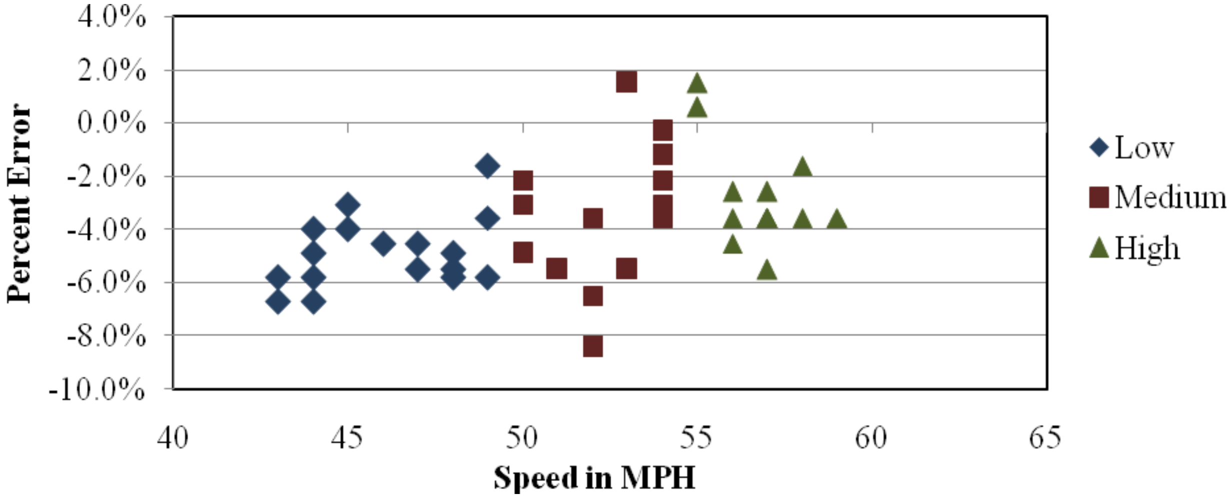


Figure 5-12 – Post-Validation Steering Axle Weight Errors by Speed – 29-Sep-10

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated tandem axle weights with acceptable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range. Distribution of errors is shown graphically in the figure.

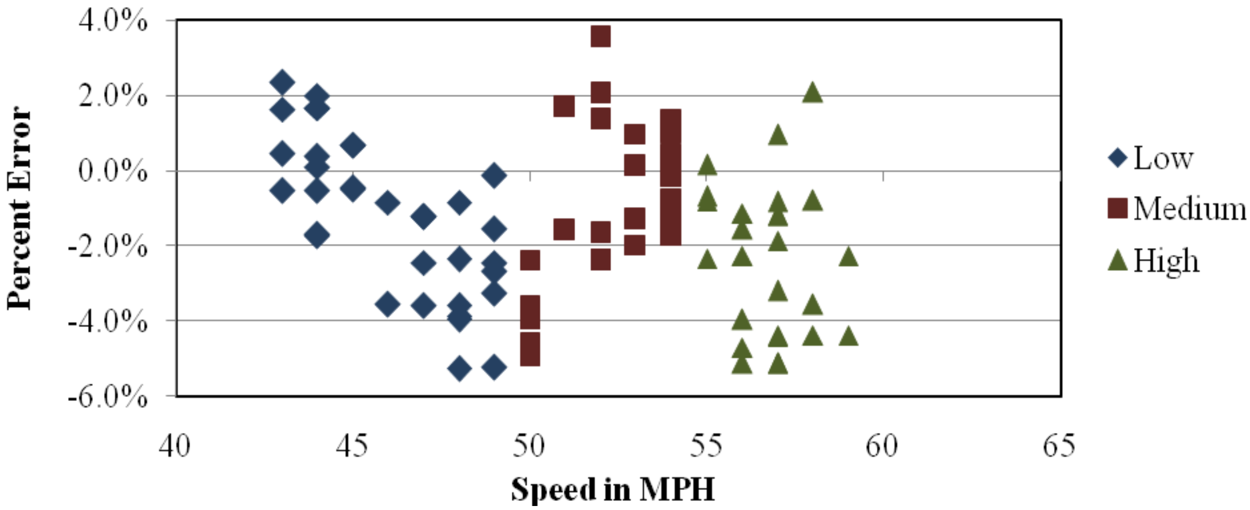


Figure 5-13 – Post-Validation Tandem Axle Weight Errors by Speed – 29-Sep-10

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-14 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck at the low and high speeds. At the medium speeds, GVW for the Primary truck is underestimated by a greater degree.

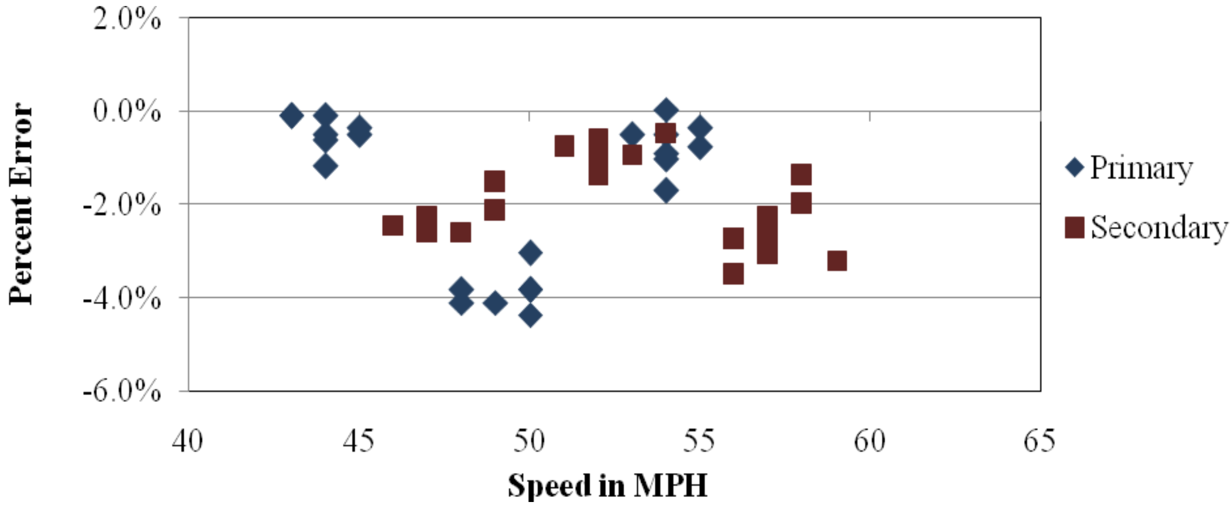


Figure 5-14 – Post-Validation GVW Error by Truck and Speed – 29-Sep-10

5.3.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from -1.0 feet to 1.6 feet. Distribution of errors is shown graphically in Figure 5-15.

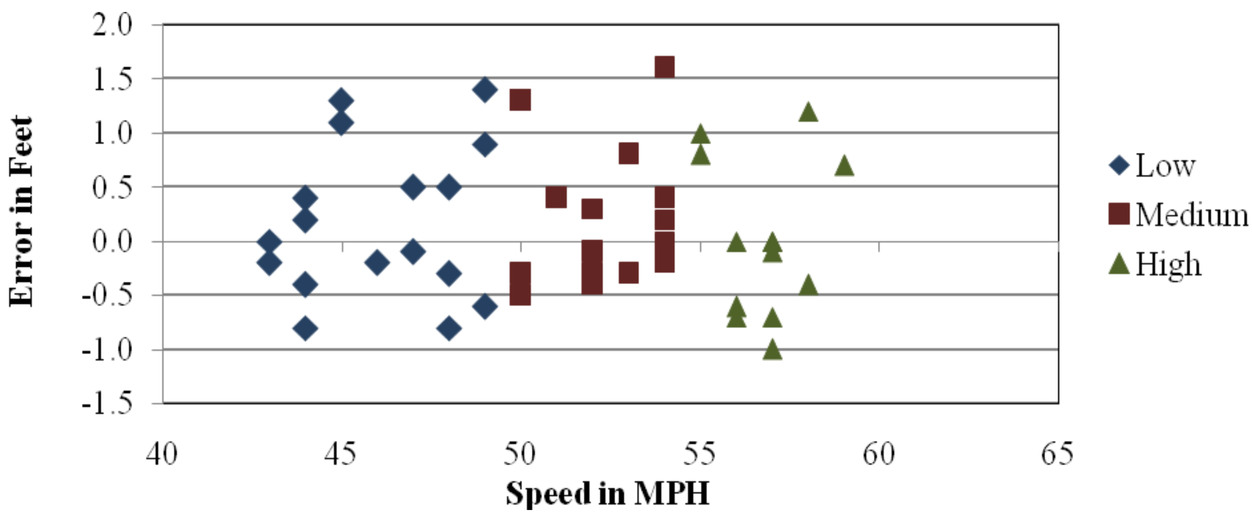


Figure 5-15 – Post-Validation Axle Length Error by Speed – 29-Sep-10

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment underestimates overall length consistently over the entire range of speeds, with errors ranging from -12.2 to -8.0 feet. Distribution of errors is shown graphically in Figure 5-16.

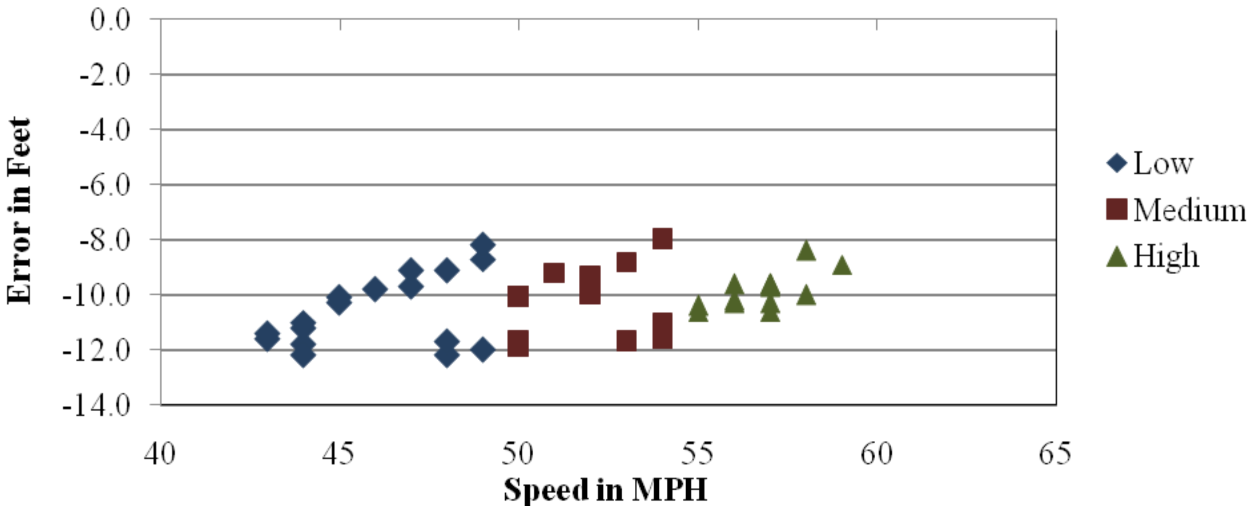


Figure 5-16 – Post-Validation Overall Length Error by Speed – 29-Sep-10

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 38.3 degrees, from 49.3 to 87.6 degrees Fahrenheit. The post-validation test runs are being reported under three temperature groups as shown in Table 5-11 below.

Table 5-11 – Post-Validation Results by Temperature – 29-Sep-10

Parameter	95% Confidence Limit of Error	Low 49.3 to 62.1 degF	Medium 62.2 to 76.0 degF	High 76.1 to 87.6 degF
Steering Axles	±20 percent	-2.5 ± 4.3%	-4.5 ± 5.0%	-4.1 ± 4.3%
Tandem Axles	±15 percent	-1.5 ± 4.4%	-1.3 ± 4.4%	-1.7 ± 4.0%
GVW	±10 percent	-1.6 ± 2.9%	-1.7 ± 2.9%	-2 ± 2.7%
Vehicle Length	±3 percent (2 ft)	-9.4 ± 2.1 ft	-10.6 ± 2.5 ft	-10.7 ± 1.9 ft
Vehicle Speed	± 1.0 mph	0.1 ± 1.5 mph	-0.1 ± 3.1 mph	-0.1 ± 2.0 mph
Axle Length	± 0.5 ft [150mm]	1.1 ± 0.6 ft	-0.2 ± 0.8 ft	-0.2 ± 0.9 ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle weights, and axle group weights.

5.3.2.1 GVW Errors by Temperature

From Figure 5-17, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates.

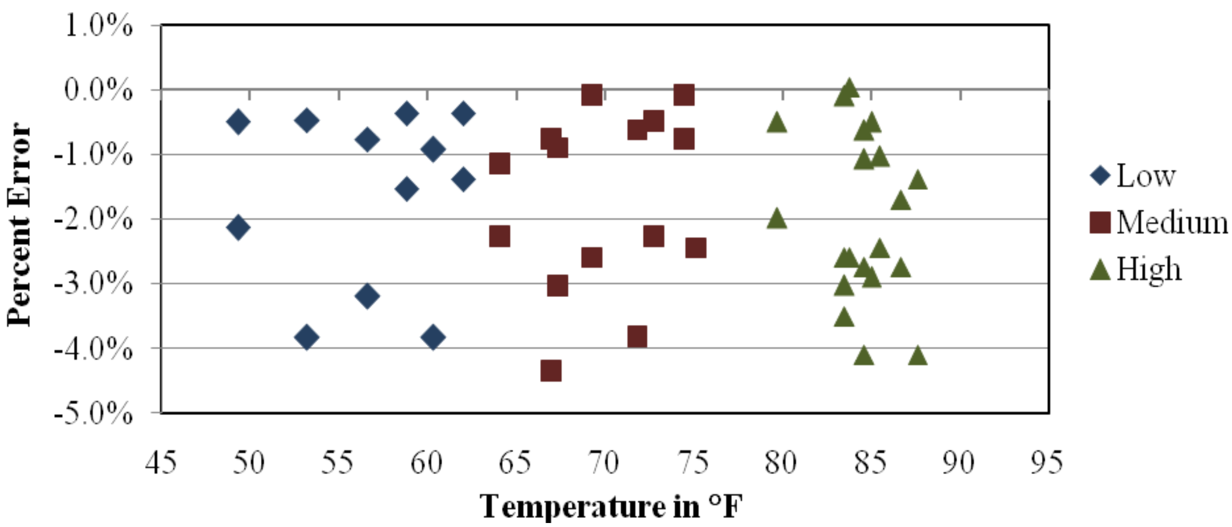


Figure 5-17 – Post-Validation GVW Errors by Temperature – 29-Sep-10

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-18 demonstrates that for steering axles, the WIM equipment underestimates at all temperatures. The range in error is similar for the different temperature groups. Distribution of errors is shown graphically in the following figure.

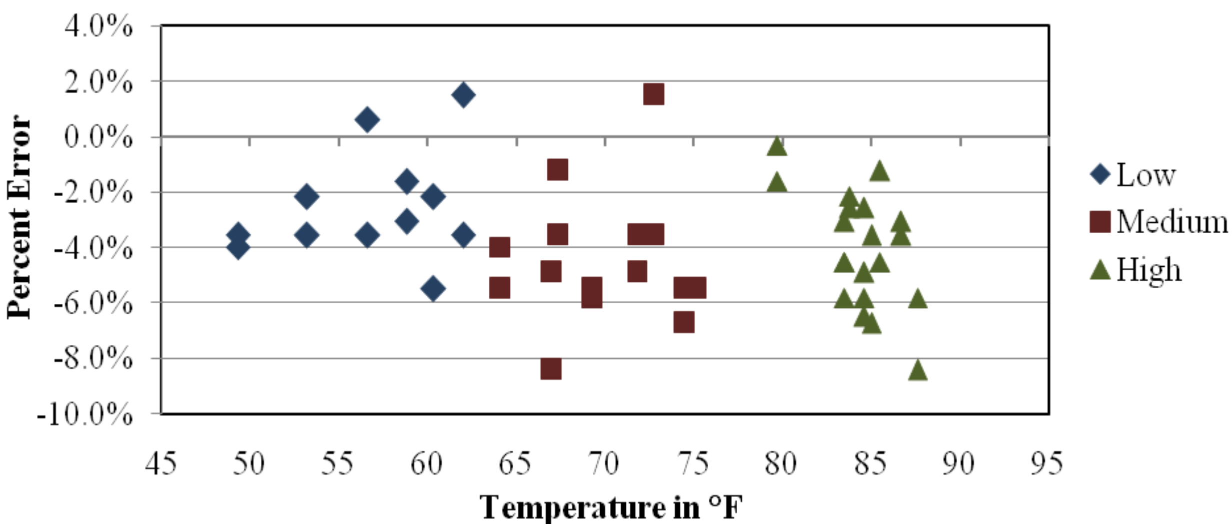


Figure 5-18 – Post-Validation Steering Axle Weight Errors by Temperature – 29-Sep-10

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-19, estimates the weight of loaded axle groups with acceptable accuracy at all temperatures. The range in tandem axle errors is consistent for the three temperature groups. Distribution of errors is shown graphically in the figure.

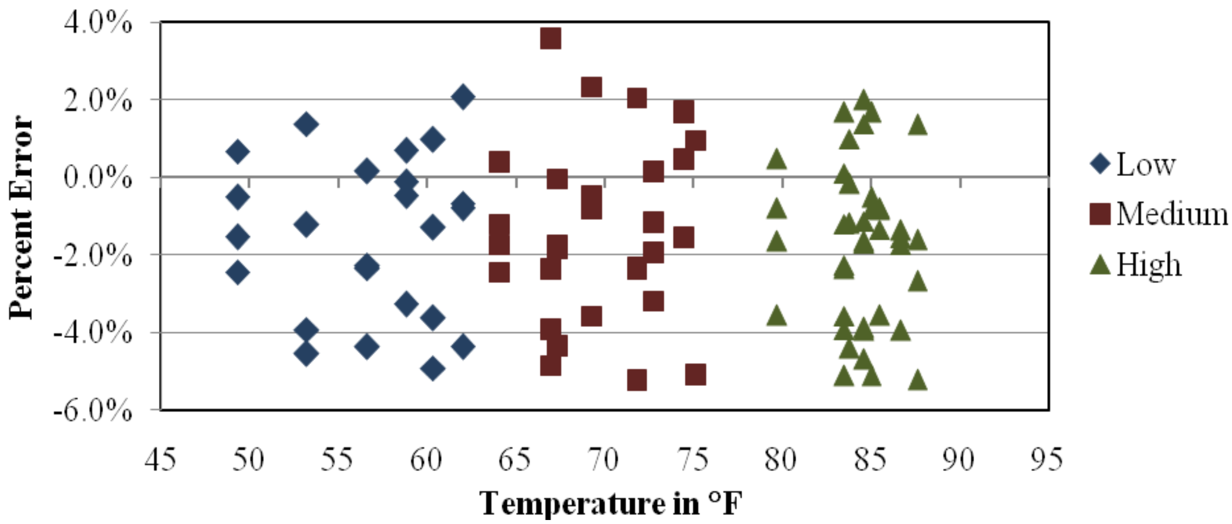


Figure 5-19 – Post-Validation Tandem Axle Weight Errors by Temperature – 29-Sep-10

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-20, when analyzed by truck type, GVW measurement errors for both trucks follow similar patterns. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in the following figure.

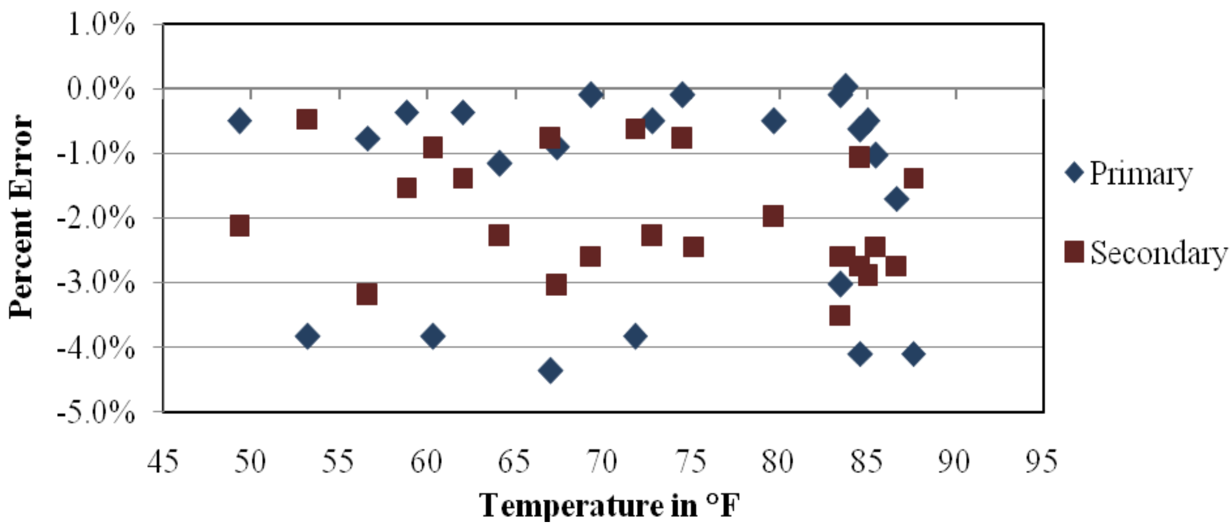


Figure 5-20 – Post-Validation GVW Error by Truck and Temperature – 29-Sep-10

5.3.3 Multivariable Analysis

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regression. The same calibration data analyzed and discussed previously are analyzed again, but this time using a more sophisticated statistical methodology. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analyses provide additional insight on how speed, temperature, and truck type affect weight measurement errors for a specific site. It is expected that multivariable analyses done systematically for many sites will reveal overall trends.

5.3.3.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. Compared to analysis described previously, the weight of "axle group" was evaluated separately for tandem axles on tractors and trailers. The separate evaluation was carried out because the tandem axles on trailers may have different dynamic response to loads than tandem axles on tractors. The measurement errors were statistically attributed to the following variables or factors:

- Truck type. Primary truck and secondary truck.
- Truck test speed. Truck test speed ranged from 43 to 59 mph.
- Pavement temperature. Pavement temperature ranged from 49.3 to 85.5 degrees Fahrenheit.
- Interaction between the factors such as the interaction between speed and pavement temperature.

5.3.3.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-12. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables. The values of the t-distribution (for the regression coefficients) given in Table 5-12 table are for the null hypothesis that assumes that the coefficients are equal to zero. The effects of none of the parameters were found statistically significant on the measurement errors of the GVW. Based on probability values, there is a good chance that the effect of the parameters on measurement errors is by chance only.

Table 5-12 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	0.6432	3.0433	0.2113	0.8338
Speed	-0.0380	0.0507	-0.7496	0.4583
Temp	-0.0084	0.0191	-0.4392	0.6631
Truck	0.2822	0.4756	0.5933	0.5567

The relationship between speed and measurement errors is shown in Figure 5-21. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-21 provides quantification and statistical assessment of the relationship.

The quantification is provided by the value of the regression coefficient, in this case -0.0380 (in Table 5-12). This means, for example, that for a 10 MPH increase in speed, the % error is decreased by about 0.3 % (0.038 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

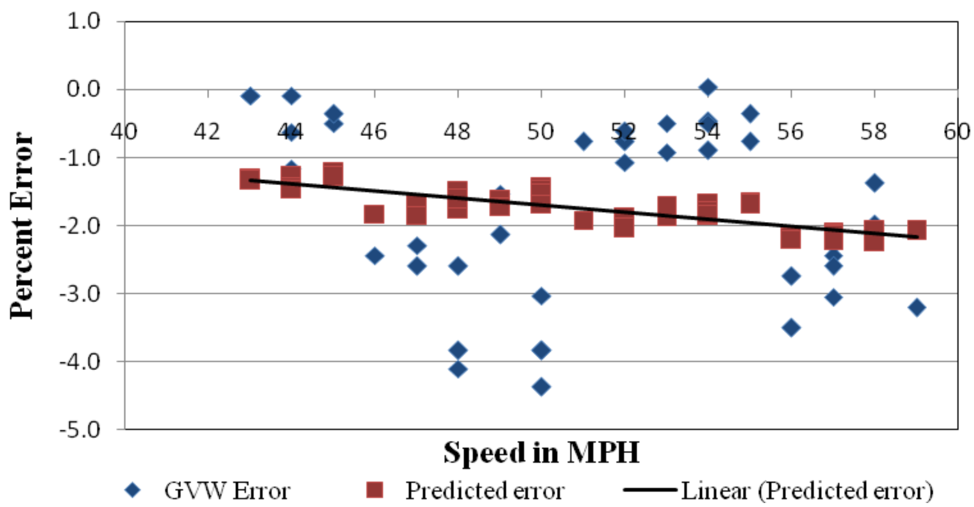


Figure 5-21 – Influence of Speed on the Measurement Error of GVW

The effect of temperature on GVW was not statistically significant. The probability that the regression coefficient for temperature (-0.0084 in Table 5-12) is not different from zero was 0.6631. In other words, there is about 66 percent chance that the value of the regression coefficient is due to the chance alone.

The interaction between speed, temperature, and truck type was investigated by adding an interactive variable (or variables) such as the product of speed and temperature. *No interactive* variables were statistically significant. The intercept was not statistically significant and does not have practical meaning.

5.3.3.3 Summary Results

Table 5-13 lists regression coefficients and their probability values for all factors and % errors evaluated. Not listed in the table are factor interactions because the interactions were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 5-13 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-13 – Summary of Regression Analysis

	Factor					
	Speed		**Temperature**		**Truck type**	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	-	-	-	-	-	-
Steering axle	0.3045	0.0000	-0.0337	0.1611	2.4813	0.0002
Tandem axle tractor	-0.1387	0.0923	-	-	-1.6688	0.0331
Tandem axle trailer	-	-	-	-	1.5242	0.0055

5.3.3.4 Conclusions

1. No parameter was statistically significant on measurement errors of GVW.

2. Temperature had a statistically significant effect on steering axle only. Since the regression coefficient was very small, it may be concluded that its effect is negligible.

3. Truck type had a statistically significant effect on the steering axle weight measurement errors and on the tandem axle weight measurement errors. However, the effects are too small to have practical significance. The regression coefficient for truck type in Table 5-13, represent the difference between the mean errors for the primary and secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). For example, the mean error in steering axle for the secondary truck was about 2.5 % larger than the error for the primary truck.

4. Truck type had no statistically significant error on GVW measurement error.

5.4 Post Visit Applied Calibration

The 85th percentile speed for trucks, based on the CDS data, is 61 mph, 6 mph above the posted speed limit of 55 mph and 6 mph above the highest test truck speed. Consequently, applied calibration should be utilized for the speeds above 55 mph, however, this system provides one speed-based compensation at 55 mph. Consequently, changes to relative compensation factors using applied calibration cannot be recommended.

Figure 5-22 is provided to illustrate the predicted GVW error with respect to the post-validation errors by speed.

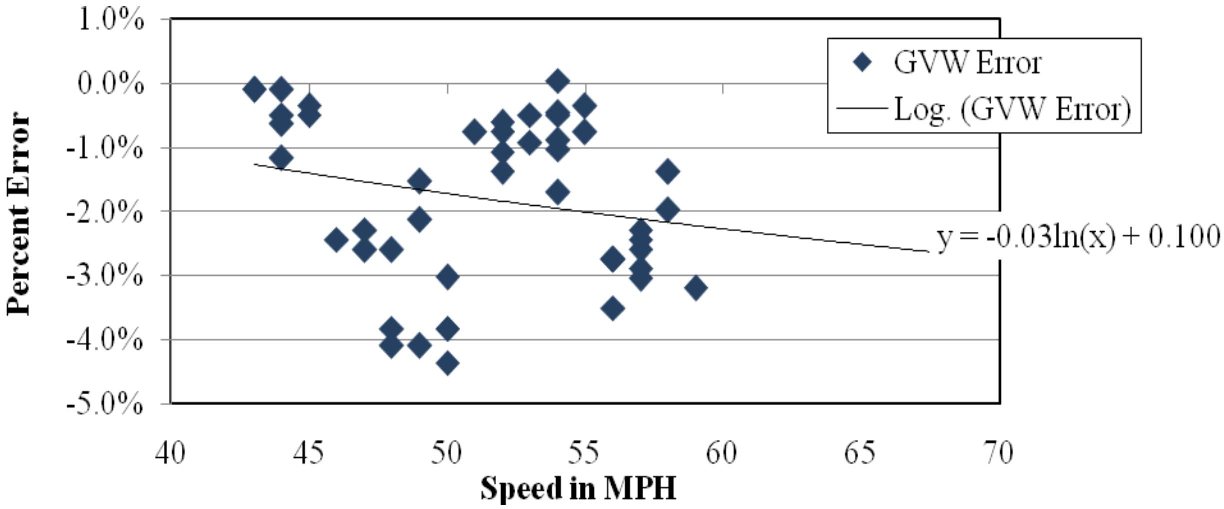


Figure 5-22 – GVW Error Trend

The final calibration factor for the 55 mph speed point that was left in place at the conclusion of the post-validation was 1000. The final distance factor was .8610.

6 Previous WIM Site Validation Information

The information reported in this section provides a summary of the performance of the WIM equipment since it was installed or since the first validation was performed on the equipment. The information includes historical data on weight and classification accuracies as well as a comparison of post-validation results.

6.1 Sheet 16s

This site has validation information from two previous visits as well as the current one as summarized in the tables below. Table 6-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

Table 6-1 – Classification Validation History

Date	Misclassification Percentage by Class										Pct Unclass
	4	5	6	7	8	9	10	11	12	13	
14-Apr-04	0	14	0	60	0	0	14	0	N/A	N/A	0
15-Apr-04	67	57	6	N/A	0	1	100	N/A	100	0	0
11-May-05	75	60	50	N/A	0	0	0	N/A	N/A	N/A	0
12-May-05	80	80	0	N/A	0	0	N/A	N/A	N/A	N/A	0
28-Sep-10	N/A	42	100	N/A	20	0	0	N/A	N/A	N/A	1

Table 6-2 data was extracted from the most recent previous validation and was updated to include the results of this validation.

Table 6-2 – Weight Validation History

Date	Mean Error and (SD)		
	GVW	Single Axles	Tandem
14-Apr-04	4.0 (4.7)	-1.8 (2.7)	8.3 (6.8)
15-Apr-04	1.8 (4.7)	-4.8 (2.3)	6.7 (7.2)
11-May-05	-1.3 (5.0)	-3.2 (5.8)	-0.9 (5.9)
12-May-05	3.5 (3.0)	1.4 (2.8)	3.9 (4.2)
28-Sep-10	-1.9 (1.1)	-4.4 (1.7)	-1.6 (1.6)
29-Sep-10	-1.8 (1.3)	-3.8 (2.2)	-1.5 (1.9)

The variability of the weight errors appears to have decreased since the site was first validated. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of GVW over time. The table also demonstrates the effectiveness of the validations in increasing the accuracy of the weight measurements.

6.2 Comparison of Past Validation Results

A comparison of the post-validation results from previous visits is provided in Table 6-3.

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 %Confidence Limit of Error	Site Values		
		15-Apr-04	12-May-05	29-Sep-10
Single Axles	±20 percent	-4.8 ± 2.3	1.4 ± 2.8	-3.8 ± 2.2
Tandem Axles	±15 percent	6.7 ± 7.2	3.9 ± 4.2	-1.5 ± 1.9
GVW	±10 percent	1.8 ± 4.7	3.5 ± 3.0	-1.8 ± -1.8

From the table, it appears that the variance for all weights have remained fairly consistent since the equipment was installed.

7 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
  - Equipment
  - Test Trucks
  - Pavement Condition
- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Pre-validation Sheet 20 – Classification and Speed Study
- Post-validation Sheet 20 – Classification and Speed Study

Additional information is available upon request through LTPP INFO at ltppinfo@dot.gov, or telephone (202) 493-3035. This information includes:

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Calibration Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 23 – WIM Troubleshooting Outline
- Sheet 24A/B/C – Site Photograph Logs
- Updated Handout Guide

WIM System Field Calibration and Validation - Photos

Ohio, SPS-1
SHRP ID: 390100

Validation Date: September 29, 2010

Photo 1 - Cabinet Exterior

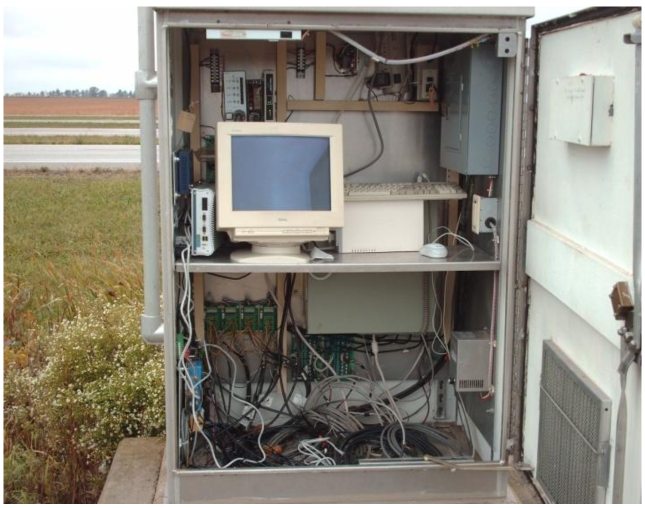


Photo 2 - Cabinet Interior

Photo 3 - Cabinet Interior

Photo 3 - Leading Loop

Photo 4 - Leading WIM Sensor

Photo 5 – Trailing WIM Sensor


Photo 7 - Power Service Box


Photo 8 - Telephone Pedestal Pavement


Photo 9 - Downstream


Photo 10 - Upstream

Photo 11 - Truck 1

Photo 12 – Truck 1 Tractor

Photo 13 - Truck 1 Trailer

Photo 14 - Truck 1 Load

Photo 15 - Truck 1 Suspension 1

Photo 16 - Truck 1 Suspension 2/3

Photo 17 - Truck 1 Suspension 4/5

Photo 18 - Truck 2

Photo 19 - Truck 2 Tractor

Photo 20 - Truck 2 Trailer

Photo 21 - Truck 2 Load

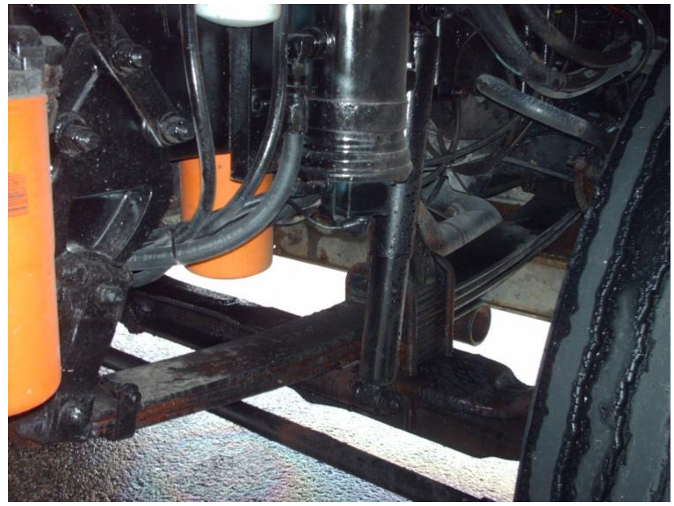


Photo 22 - Truck 2 Suspension 1

Photo 23 - Truck 2 Suspension 2/3

Photo 24 - Truck 2 Suspension 4


Photo 25 - Truck 2 Suspension 5

Traffic Sheet 16	STATE CODE:	39
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	390100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	9/28/2010

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 9/28/10

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE (Select all that apply):

a. Load Cells c.
b. Inductance Loops d.

5. EQUIPMENT MANUFACTURER: Mettler

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 21

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	9	air	air
Truck 3:	0	0	0

7. SUMMARY CALIBRATION RESULTS (expressed as a %):

Mean Difference Between -

Dynamic and Static GVW:	-1.9%	Standard Deviation:	1.1%
Dynamic and Static Single Axle:	-4.4%	Standard Deviation:	1.7%
Dynamic and Static Double Axles:	-1.6%	Standard Deviation:	1.6%

8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED: 3

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	45.0	to	49.0	16
b.	Medium	-	49.1	to	54.0	16
c.	High	-	54.1	to	60.0	10
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	39
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	390100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	9/28/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 1000

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

CLASSIFIER TEST SPECIFICS

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:		FHWA Class		-	
FHWA Class 8:		FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 1.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-512-6638

E-mail: dwolf@ara.com

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 39 SPS WIM ID: 390100 DATE (mm/dd/yyyy) 9/29/2010

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 9/29/10

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE (Select all that apply):

a. Load Cells
c.
b. Inductance Loops
d.

5. EQUIPMENT MANUFACTURER: Mettler

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 24

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	9	air	air
Truck 3:	0	0	0

7. SUMMARY CALIBRATION RESULTS (expressed as a %):

Mean Difference Between -

	Mean		
Dynamic and Static GVW:	-1.8%	Standard Deviation:	1.3%
Dynamic and Static Single Axle:	-3.8%	Standard Deviation:	2.2%
Dynamic and Static Double Axles:	-1.5%	Standard Deviation:	1.9%

8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED: 3

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	43.0	to	49.0	17
b.	Medium	-	49.1	to	54.0	17
c.	High	-	54.1	to	59.0	13
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 39 SPS WIM ID: 390100 DATE (mm/dd/yyyy) 9/29/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 1000

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

CLASSIFIER TEST SPECIFICS

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:		FHWA Class		-	
FHWA Class 8:		FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 1.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-512-6638

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 39 SPS WIM ID: 390100 DATE (mm/dd/yyyy) 9/28/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	9	17578	64	9	58	9	18342	59	9
56	9	17583	55	9	61	9	18373	61	9
55	9	17605	53	9	55	8	18436	55	8
50	9	17614	46	9	58	9	18469	58	9
53	9	17685	53	9	57	9	unk	59	9
58	9	17710	51	9	60	9	18543	54	9
50	3	17719	54	5	60	9	18555	57	9
56	9	17751	56	9	53	9	18572	54	9
54	9	17758	54	9	53	5	18616	59	5
59	9	17784	54	9	60	9	18627	57	9
62	9	17825	59	9	57	9	18700	57	9
58	9	17830	55	9	58	9	18738	54	9
57	9	17861	55	9	56	9	18776	53	9
54	9	17905	53	9	55	9	18920	54	9
54	9	17913	57	9	58	9	18935	53	9
56	9	17948	52	9	58	9	19030	55	9
58	9	17992	55	9	55	9	19044	53	9
55	9	18002	55	9	56	9	19255	53	9
60	9	18039	57	9	57	9	19304	54	9
51	9	18047	59	9	53	9	19369	54	9
68	3	18088	60	5	57	9	19426	57	9
57	9	18108	57	9	60	9	19453	58	9
56	9	18155	59	9	58	9	19462	54	9
65	4	18248	56	6	53	8	19471	53	8
60	9	18286	61	9	59	9	19484	52	9

Validation Test Truck Run Set - Pre

Sheet 1 - 0 to 50　　Start: ____________　　Stop: ____________

Recorded By: djw　　Verified By: kt

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 39 SPS WIM ID: 390100 DATE (mm/dd/yyyy) 9/28/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
54	5	19534	53	5	56	9	6591	53	9
54	9	19549	56	9	53	5	6622	50	5
54	4	19556	57	5	56	9	6645	59	9
60	9	19574	55	9	50	9	6655	51	9
57	9	19601	57	9	57	9	6746	53	9
56	9	19627	53	9	58	9	6837	53	9
57	9	19819	57	9	62	9	6881	60	9
60	9	19905	56	9	62	9	6977	54	9
58	9	19929	62	9	56	8	7004	59	5
55	8	19972	58	8	55	9	7010	59	9
58	9	20027	55	9	58	9	7013	58	9
58	10	20052	56	10	59	9	7186	57	9
60	9	20190	60	9	62	9	7206	54	9
59	9	6083	58	9	65	9	7218	58	9
58	9	6096	55	9	67	9	7292	67	9
58	10	6118	61	10	55	9	7309	53	9
60	9	6195	61	9	57	9	7341	52	9
60	5	6222	60	5	58	9	7352	60	9
65	5	6251	55	5	56	9	7382	51	9
60	9	6260	52	9	59	3	7429	60	5
58	9	6272	55	9	60	9	7511	58	9
55	8	6296	57	8	60	9	7625	56	9
56	9	6323	54	9	59	9	7643	57	9
41	5	6387	41	5	57	9	7657	59	9
52	15	6562	55	9	56	5	7674	55	5

Validation Test Truck Run Set - Pre

Sheet 2 - 51 to 100 Start: ____________ Stop: ____________

Recorded By: djw Verified By: kt